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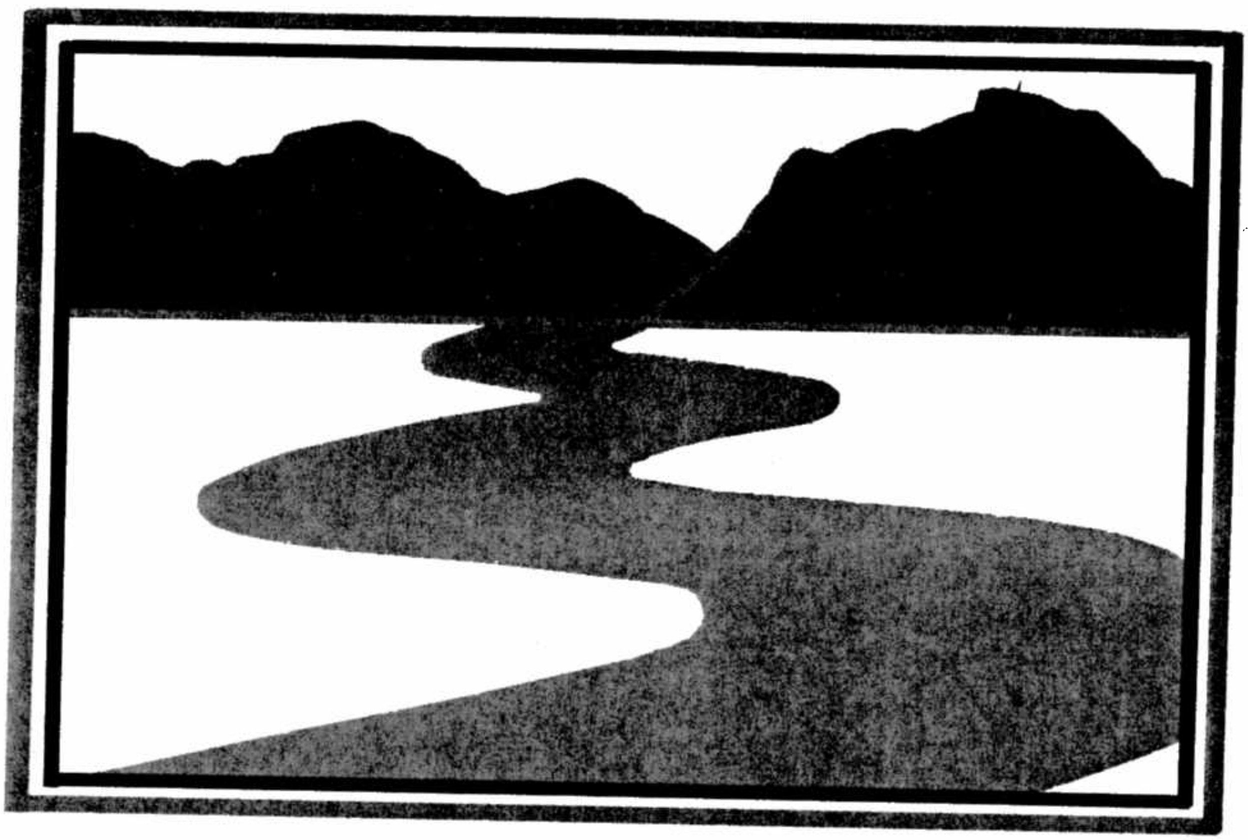
A GUIDE TO FILING APPLICATIONS FOR INSTREAM FLOW WATER RIGHTS IN ARIZONA



ARIZONA DEPARTMENT OF WATER RESOURCES

DECEMBER, 1991

A GUIDE TO FILING APPLICATIONS FOR INSTREAM FLOW WATER RIGHTS IN ARIZONA

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I. INTRODUCTION

Due to the increasing demands placed on Arizona's limited water resources and legal mandates to protect and preserve natural resources, the preservation of instream flows for the maintenance of fish, wildlife and associated habitat, and recreational uses has become critical. Instream flow, as defined in this report, is the maintenance flow necessary to preserve instream values such as aquatic and riparian habitats, fish and wildlife and water-based recreation in a particular stream or stream segment.

Instream flow issues are multi-disciplinary. Rates of impoundment, diversion and groundwater use threaten to adversely reduce streamflows or even de-water streams to the present and future detriment of aquatic and terrestrial resources. As a result of the high demand for water by various competing interests, the value placed upon water has increased markedly. Although the value of water withdrawn from a stream for agricultural, industrial, mining or municipal use has been commonly recognized, instream uses have only recently begun to be recognized for their importance.

Instream flows are inherently linked to riparian areas and their associated resources. In addition to adequate available flows, fish, wildlife and many recreational activities depend on or are enhanced by the maintenance of these areas. On February 14, 1991, Governor Rose Mofford issued Executive Order NO. 91-6 dealing with the importance of riparian areas in Arizona. The Executive Order contains the following statement of policy:

> "In recognition of the critical nature of riparian areas to the State, it is hereby determined that the policy of the State of Arizona shall be:
>
> (a) To recognize that the protection and restoration of riparian areas are of critical importance to the State;
> (b) To actively encourage and develop management practices that will result in maintenance of existing riparian areas and restoration of degraded riparian areas;
> (c) To promote public awareness through the development of educational programs of the benefits and values of riparian areas and the need for their protection and careful management;

(d) To seek and support cooperative efforts and local group and citizen involvement in the protection, maintenance and restoration of riparian areas;

(e) **To encourage the preservation, maintenance and restoration of instream flows throughout the State;**

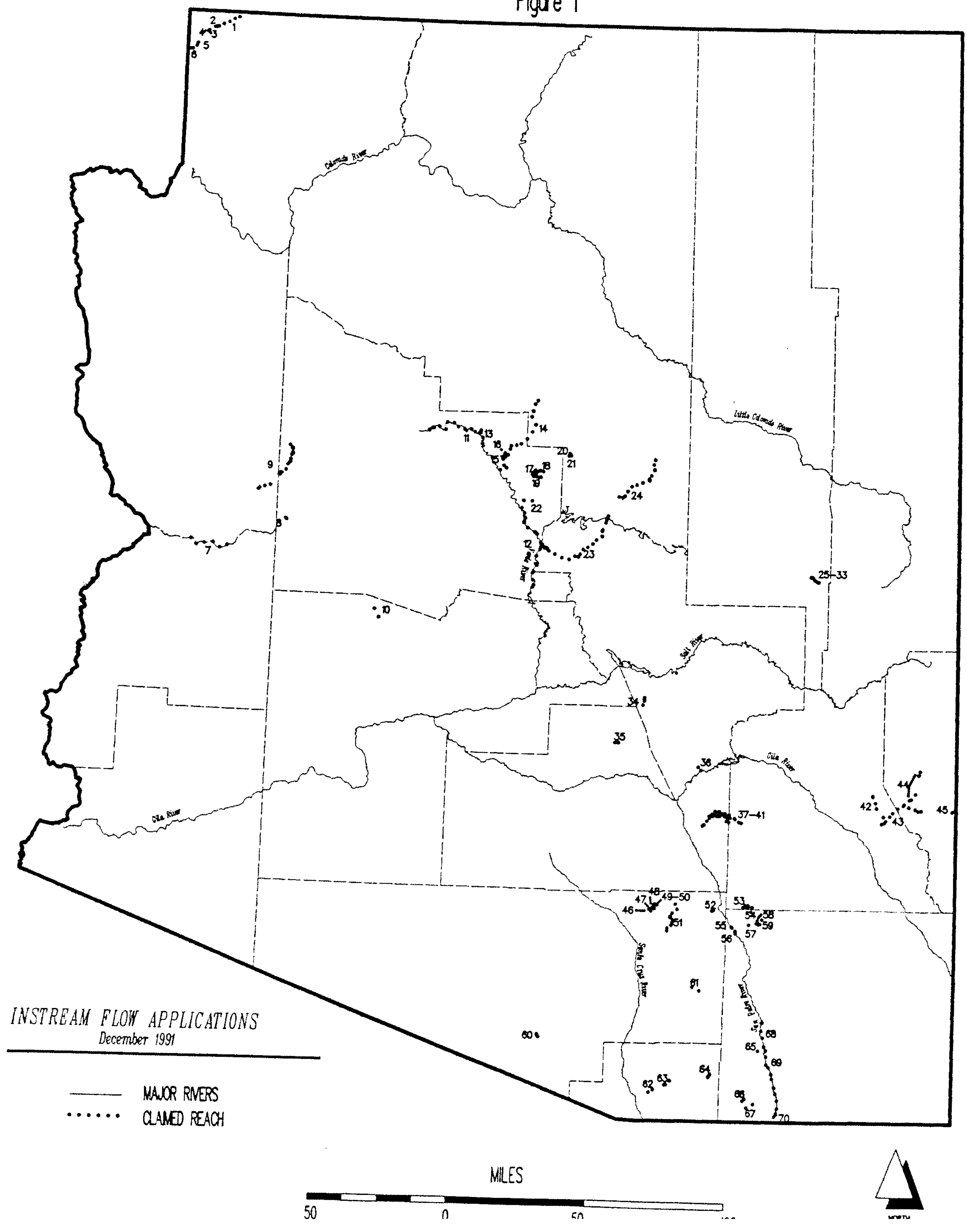
(f) That any loss or degradation of riparian areas will be balanced by restoration or enhancement of other riparian areas of equal values and functions."

Development of an instream flow water right program has been in progress since December, 1986. In order to give full consideration to the needs of instream flow applications, the Arizona Department of Water Resources (ADWR) organized an Instream Flow Task Force in December, 1986. Individuals from both federal and state governments, the universities and the private sector were invited to participate. Two subcommittees were established to deal with technical issues. The Biological Subcommittee was charged with the investigation of various methodologies in use for evaluating flow requirements for wildlife habitat and to make recommendations on those techniques which would be most useful in Arizona. The Hydrologic Subcommittee was asked to investigate methods for evaluating historical flow information for streams which may or may not have gaged records. The quality of the input which ADWR received from the Task Force was outstanding and extremely valuable. For the most part, this report is the product of the work of the Task Force. ADWR wishes to acknowledge the tremendous effort given by all those who participated in its preparation.

In addition to the work of the Task Force, ADWR felt it would be useful to obtain first hand experience in processing instream flow applications (Figure 1.). Therefore, several applications were selected to serve as prototypes. This process resulted in the issuance of three permits. The Bureau of Land Management received permits for instream flow water rights on Aravaipa Creek and Peoples Canyon and the Arizona Nature Conservancy received a permit for the Hassayampa River Preserve. The knowledge and experience gained by the prototype process was extremely valuable in determining the procedures to use for other applications, and ADWR would also like to express its appreciation to those individuals who assisted in that effort.

Assessment of water availability and beneficial use requirements is necessary to support an application for a permit to appropriate surface water. Applicants will be required to collect and analyze data in a manner sufficient to support the requested appropriation. However, the amount and type of data collected and the methods used to evaluate the data are dependent upon several factors. These factors vary for each instream flow application. Despite this variability, ADWR has determined minimum criteria for substantiating instream flow requests. In addition, this report

Figure 1



Colorado River
Little Colorado River
Salt River
Gila River
Gila River
Santa Cruz River
San Pedro River
INSTREAM FLOW APPLICATIONS
December 1991
MAJOR RIVERS
CLAIMED REACH
MILES
50
0
50

INSTREAM FLOW WATER RIGHT APPLICATIONS

1. 33-94819 Virgin River
2. 33-96133 Virgin River
3. 33-96134 Virgin River
4. 33-94843 Beaver Dam Wash
5. 33-94865 Virgin River
6. 33-94866 Virgin River
7. 33-94245 Bill Williams River
8. 33-90410 Peoples Canyon Creek
9. 33-89119 Francis/Burro Creek
10. 33-92304 Hassayampa River
11. 33-94374 Verde River
12. 33-90309 Verde River
13. 33-90113 Sycamore Creek
14. 33-90106 Oak Creek
15. 33-90111 Sheepshead Creek
16. 33-90114 Spring Creek
17. 33-90109 Red Tank Draw
18. 33-90112 Wet Beaver Creek
19. 33-90108 Walker Creek
20. 33-95370 Foster Creek
21. 33-95371 Jones Creek
22. 33-90110 West Clear Creek
23. 33-90310 East Verde River
24. 33-90107 East Clear Creek
25. 33-90311 Billy Creek
26. 33-94847 Billy Creek
27. 33-94848 Billy Creek
28. 33-94850 Billy Creek
29. 33-94851 Billy Creek
30. 33-94852 Billy Creek
31. 33-94853 Billy Creek
32. 33-94855 Billy Creek
33. 33-94863 Billy Creek
34. 33-89109 Pinto Creek
35. 33-92298 Queen Creek
36. 33-90252 Mescal Creek
37. 33-95771 Aravaipa Creek
38. 33-95488 Aravaipa Creek
39. 33-95489 Aravaipa Creek
40. 33-95490 Aravaipa Creek
41. 33-87114 Aravaipa Creek
42. 33-90250 Bonita Creek
43. 33-94379 Gila River
44. 33-90251 San Francisco River
45. 33-90253 Apache Creek
46. 33-93286 Alamo Canyon
47. 33-93283 Montrose Canyon
48. 33-93284 Romero Canyon
49. 33-93285 Cargodera Canyon
50. 33-93282 Cargodera Canyon
51. 33-93232 Sabino Canyon
52. 33-90249 Buehman Canyon
53. 33-94369 Redfield Canyon
54. 33-94370 Swamp Springs Canyon
55. 33-96126 San Pedro River
56. 33-96127 San Pedro River
57. 33-94372 Hot Springs Canyon
58. 33-95454 Wildcat Canyon
59. 33-94371 Bass Canyon
60. 33-78418 Thomas Wash
61. 33-89090 Cienega Wash
62. 33-93287 Sonoita Creek
63. 33-78420 Sonoita Creek
64. 33-78421 O'Donnell Creek
65. 33-95487 Babocomari Creek
66. 33-78419 Ramsey Canyon
67. 33-95366 Miller Canyon Creek
68. 33-90103 San Pedro River
69. 33-95789 San Pedro River
70. 33-95780 San Pedro River

describes some of the methodologies available to assess instream flows in Arizona. However, only a few of those techniques are discussed. Many other applicable methods exist and it is impossible to address them all. Despite these limitations, an applicant is given an idea of techniques available and is made aware of the minimum requirements for documenting an instream flow application. New methods will continue to be developed, while existing ones will evolve and improve.

While this report does specify minimum criteria necessary for substantiating an instream flow request, it does not mandate the use of any particular technique for any specific situation. Since each stream is unique, this report is intended to direct instream flow applicants to assess streams where an instream flow right may be sought with a method that is commensurate with:

- the legal challenge the application is likely to face;
- the water requirement of the claimed beneficial uses and;
- the characteristics of the stream.

Applicants are encouraged to meet with ADWR personnel at the earliest possible stages of an instream flow evaluation process. The intent of this activity is to formulate a program of study that will best assess an individual instream flow request and to determine specific requirements for that application.

While methods for determining the amount of water necessary for consumptive uses have been developed over a number of years, quantifying streamflow needed for instream uses is a fairly new science. The focus of this report is to present and describe methodologies for: 1) quantifying the amount of water necessary for instream fish, wildlife or recreational uses and, 2) quantifying the availability of requested flows during claimed periods of beneficial use. In addition, the water right appropriation process for instream uses is discussed.

This report presents criteria which must be satisfied by an applicant for an instream flow appropriation and methodologies that may be useful for assessing streamflow. The report addresses new appropriations and does not apply to the conversion of existing consumptive use rights to instream flow rights. Other issues, such as who may apply for and hold instream flow water rights, will need to be addressed through the rule-making process. As these issues are resolved they will be incorporated into the instream flow appropriation process and the guide will be revised to accommodate those additions.

II. INSTREAM FLOW APPROPRIATION PROCESS AND REQUIREMENTS

The appropriation of public water for the purpose of maintaining instream flows requires the assessment of the streamflow required for the stated purpose and the measurement of the availability of streamflow to meet that purpose. Stream characteristics, morphology, the amount of streamflow required for the proposed beneficial use, the availability of water supply, and legal aspects may vary considerably for each proposed instream flow appropriation. Therefore, the method(s) available to assess need and supply may also differ.

Despite the variability of this type of appropriation, the Arizona Department of Water Resources has identified certain minimum requirements for assessing the need and available supply as substantiating evidence for the proposed appropriation. The requirements are divided into 7 steps and are presented in accordance with the basic surface water appropriation process. This process includes application, permit and certification phases.

The process of appropriating an instream flow for a stated beneficial purpose is as follows:

STEP 1. Pre-Application Conference with Arizona Department of Water Resources

The applicant is responsible and is encouraged to contact the Surface Water Rights Section Manager, Operations Division to set an appointment to meet with Department technical and administrative staff for the purpose of discussing the proposed instream flow appropriation. The purpose of the meeting is to make the applicant aware of the Department's requirements for appropriating public water for this type of beneficial use, to answer any questions, and to avoid potential problems during the application process. The applicant may also be able to determine how other applicants in similar circumstances designed their data collection and analysis programs.

The meeting should preferably occur prior to any data collection, but must occur prior to analysis of the minimum of one year of streamflow measurement data required to obtain a permit. There are several methodologies available for assessing the need for an instream flow and the availability of the water supply. Meeting with the Department's staff early in the appropriation process provides the applicant with direction regarding which assessment method would adequately determine streamflow requirements and availability.

STEP 2. Begin or continue data collection

The collection of streamflow measurements should be one of the first steps of the assessment process because nearly all methods of assessing instream flow requirements are dependent upon measured streamflow data. This data also provides the applicant and the Department with information regarding the availability of the water supply during a given time period. In addition, the measure of any eventual permitted beneficial use will be stated in terms of the rate of flow.

STEP 3. File the appropriations application

The Application for Permit to Appropriate Public Water must be filed with the Department's Operations Division, located at 15 South 15th Avenue in Phoenix. The application must be submitted on a form provided by the Department. A sample copy of the application form is included in Appendix A of this document for reference.

The submitted application is subject to review for acceptance. Therefore, all questions on the form must be answered as completely as possible. If a submitted application is found to be in error or deficient, the applicant will be required to correct the application, or it may be subject to rejection. Additional time may be granted if for good cause and if requested in writing.

The filing date of the application is the priority date of the appropriation. If an application is found to be deficient and the applicant fails to resubmit the correct application within 60 days of notice of the error or omission, the Department will void the original priority date.

Monthly or seasonal streamflow rates originally claimed on an application to appropriate may be amended based on the results of the study described in Step 4. This is not considered a deficiency in the original application and can be accomplished without the loss of the priority date.

STEP 4. Conduct data analysis and submit report

Prior to this step, the applicant should have met with the Department's staff to formulate a proposed method of study to determine instream flow requirements for the proposed beneficial use and the availability of the water supply to meet those requirements.

A minimum of one year of streamflow measurement data is required to be submitted by the applicant before the Department will issue a permit to appropriate the water. In addition, the applicant is required to submit a report of the results and conclusions of the study based on the methodology developed in the prior meeting with the Department's staff.

The study should be submitted at the time of filing of the appropriation application, but must be submitted no later than two years after the filing date. If the required report is not submitted by the specified deadline, the application will be rejected.

The submitted report must, at a minimum, include:

- ✓ **A description of both the streamflow data-collection method used in the study and method of assessment of streamflow requirements for the proposed appropriation.**

- ✓ **A description of the beneficial use intended for the instream appropriation. At a minimum, this description must describe the relationship between the required streamflow and the benefits received by fish, wildlife and/or recreation activities.**

- ✓ **The analysis and raw data of actual streamflow measurements of the proposed source of water collected for a minimum of one year, with at least one on-site measurement taken each month of claimed beneficial use or at least three random on-site measurements taken during each primary flow season (e.g., during spring runoff, prior to onset of monsoonal rains) of claimed beneficial use. Separate flow rates must be requested for each month or each flow season.**

- ✓ **A description of the streamflow and the resources associated with the instream flow. This includes fish and wildlife species, riparian vegetation and stream channel and flow characteristics.**

- ✓ **An assessment of the quantity of water historically available at the location of the proposed instream appropriation.**

STEP 5. Public notice of application and opportunity for protest

Once the Department judges an application to be complete and correct and has received an instream flow report that substantiates claimed flows, the Department will issue official public notice of the proposed appropriation. The proposed appropriation is subject to protest during the 60 day period from the date the public notice is issued. The proposed appropriation may be protested on the grounds of impact to a prior-vested water right, the appropriation is not in the best interest of the public, or that the appropriation presents a hazard to public safety.

If a protest is submitted against the proposed appropriation, the applicant should attempt resolution with the protestant. If a protest is not resolved within a reasonable amount of time, the Department will review the application and the submitted protest. The Department may then conduct a public hearing on the matter, dismiss the protest, or reject the application.

The process of resolution of any submitted protests may consume substantial amounts of time, and delay any eventual issuance of a permit. It is therefore advantageous to the applicant to have determined valid and supportable flow-rate requests. Strict control and attention to detail in conducting streamflow measurements may prevent unnecessary delays in the administrative procedure.

STEP 6. Issuance of a Permit to Appropriate Public Water

When the analysis of the submitted report and data by the Department's staff concludes that the minimum requirements have been satisfied, a permit is issued to the applicant. In addition to ADWR review, technical review and comment on the report may be requested from the Arizona Game and Fish Department. The permit may contain conditions or other stipulations concerning the perfecting of the instream appropriation.

STEP 7. Issuance of a Certificate of Water Right

The permit holder is required to demonstrate that the instream flow water right is being used in a manner consistent with terms of the issued permit. A minimum of four years of streamflow measurement data is required before the Department may consider the proposed appropriation perfected. Prior to the permit becoming a candidate for certification the applicant must submit to the Department:

- ✓ Proof of Appropriation
- ✓ Affidavit of Appropriator
- ✓ Minimum of 4 years of streamflow data
- ✓ Analysis of streamflow data.

If a total of 4 years of data was already available at the time the permit was issued, it is possible to move to the certificate stage quite promptly. When an analysis of the submitted Proof of Appropriation and supporting evidence concludes that the appropriation has been perfected, the Department may then issue the certificate.

While an instream flow water right holder is not required to submit streamflow information to the Department following certification, continued streamflow measurement is strongly advised. Lack of adequate data may result in the inability of a right holder to prove infringement on an instream flow right.

III. INSTREAM FLOW RESOURCE ASSESSMENT METHODS

An abundance of methodologies quantifying instream flow requirements of fish, and to a much lesser degree recreation and wildlife, have been proposed over the past 15 years. Some methodologies are species, habitat or activity specific; others require U.S. Geological Survey (USGS) flow records; some involve complex hydraulic simulation using comprehensive field data in conjunction with computer programs; while other methodologies attempt to predict species usage through evaluation of key habitat parameters.

Numerous states have evaluated selected methodologies to determine which are most appropriate for their particular needs (Prewitt and Carlson, 1979; Nelson, 1978; Wesche and Rechard, 1980). Due to regional variability in aquatic resources, state agency objectives, funding and time constraints and instream flow legislation, no single methodology suits the needs of all stream conditions and instream values of every state. Indeed, few states rely solely upon one methodology. McKinney and Taylor (1988) report that of the nine western states with instream flow programs, all nine use standard setting methods, and six of the nine utilize both standard setting and incremental methods to quantify instream flows. Standard setting methods identify minimum flow standards required to protect a stated beneficial use, while incremental methods quantify flow-related trade-offs between various instream flow levels and the protection of instream flow values. The following list includes key considerations in selecting the most appropriate instream flow methodology:

- Presently used and accepted methods.
- Output desired (e.g., reconnaissance-level, legal defensibility, credibility)
- Present legislation pertaining to instream flow.
- Time, money and labor constraints.
- Capability of method to predict probable consequences of flow modifications.
- Suitability to project scope.
- Flexibility of method (i.e., ability to refine, modify method to meet specific needs).
- Target management species (e.g., game, non-game, threatened and endangered).
- Assessment of fisheries, wildlife and recreational value priorities.

- Availability of historical flow records.
- Anticipated level of controversy.

Methodologies available to quantify instream flows for fish, wildlife and recreation vary in sophistication and precision. These range from simple visual judgements pertaining to the sufficiency of historical flows to elaborate computer models that can estimate flow requirements of specific fish, wildlife and recreational needs. Standard setting methods are generally applicable to streams where applications are not likely to be protested and/or water rights are unlikely to face legal action.

Methodologies used for streams in which applications may face significant protests by other water users or where water rights are likely to require resolution through legal action, should be commensurate with the perceived legal challenge and the need for detailed study. These streams are generally of critical importance to state or federal natural resource management agencies. In most instances, these surface waters support populations of either rare and endangered or economically valuable fish and/or wildlife species or are important for their recreational values. This could include high recreational use areas or areas suited for wild and scenic or riparian conservation area designations. Intensive incremental methodologies are usually recommended for these situations, however, some standard setting methods may be applicable.

In Arizona, many of the streams where instream flow applications have been or may be filed in the future do not exhibit the controversial aspects mentioned above. These streams may be in headwater locations, in areas where springs allow for surface flow for very short distances before water percolates back to the groundwater table, or where base flows are usually very small. In these types of applications, ADWR will allow the resource assessment technique to be a narrative description which correlates the requested flow with the fish, wildlife, or recreation benefits expected from the appropriation. This method may be used only in combination with requests for median monthly flows and where the appropriation request does not include any increase in consumptive use. This approach was used successfully in the Peoples Canyon and Hassayampa River Preserve prototype permits. It should be noted that a request of median streamflow rates would preclude the inclusion of flood flows. To obtain an instream flow water right for streamflows greater than the median flow rate, an applicant must utilize a technique, such as an incremental methodology, that adequately quantifies the relationship between the claimed beneficial uses and streamflow.

The intent of this portion of the report is to provide an overview of the various instream flow methodologies most applicable to conditions in Arizona. Methodologies are evaluated on their strengths, weaknesses, adaptability and appropriateness. Additional methods are identified and briefly described in the Appendix B.

A. STANDARD SETTING METHODS

Standard setting or simple incremental methods can be divided into "non-field" and "habitat retention" methods (McKinney and Taylor, 1988). Non-field methods, including the Tennant and Northern Great Plains methods, base flow requirement decisions on historical flow records rather than on field observations. Habitat retention techniques, on the other hand, examine relationships between discharge and generalized fish and wildlife habitat and recreational use indices to derive flow recommendations. These techniques are referred to as habitat retention methods because they identify flow levels where desirable aquatic habitat characteristics are retained. Some of the habitat retention techniques may be utilized in either a single or multiple transect scenario.

1. Non-Field Methods

These methods are quick and easy to apply when data are available, but are inflexible and have limited accuracy. They are generally used to set interim instream flow standards or for reconnaissance-level projects.

Narrative Justification Method

Many stream reaches where instream flow applications have been filed or are likely to be filed have small baseflows or are located in headwater areas where little or no impact on other water users is likely. In recognition of these types of circumstances ADWR will allow abbreviated studies which document the beneficial use aspects of the proposed instream flow. In many cases the relationship between a perennial stream and the benefits for fish, wildlife or recreation have already been recognized in other ways such as designation of the area as a wilderness, a wildlife preserve, or as an area of unique waters. In circumstances where ADWR feels that documentation of the requested instream flow can rely primarily on hydrologic records which demonstrate the likelihood that beneficial use will occur at a rate of median monthly flows, this shortcut technique will be allowed. Two examples of this method were the applications by the Bureau of Land Management for Peoples Canyon Creek and by the Arizona Nature Conservancy for the Hassayampa River Preserve.

In the narrative justification method the applicant must describe the beneficial uses for which the instream flow right is sought. The physical setting should be described as well as any fish and wildlife resources whose existence depends either directly or indirectly on the streamflow. If unique habitat is located along the stream reach or if threatened or endangered species are dependent on the flow, this information should be documented. If recreation is the beneficial use, the description should provide information on accessibility to the site, the type of recreational activity and the number of visitors. The key aspect of this method is to demonstrate the dependence relationship between the beneficial uses and the instream flow. In that regard, effort should be made to describe possible negative effects if for some reason the flow would decrease below the requested levels.

Tennant or Montana Method

This is a quick, easy method that has been applied to stream reaches with USGS records. While its applicability to Arizona streams is limited, it has provided a basis for the development of other more accurate methods and deserves discussion in this report.

On the basis of field studies in Montana, Wyoming and Nebraska, Tennant (1976) found that habitat quality was relatively consistent in most streams displaying similar average flow regimes. Therefore, certain recommended percentages of the mean annual flow (MAF) are recommended for various management objectives. Ten percent of the average flow is a minimum instantaneous flow that will generally sustain short-term survival habitat for most aquatic life forms, limited nesting, denning and refuge habitat for terrestrial species and limited recreational opportunities. Thirty percent of the MAF is recommended to sustain: 1) good survival habitat for aquatic life forms; 2) good denning, nesting and refuge habitat for terrestrial species; and 3) adequate water quantity and quality for general recreation. Sixty to 100% of the MAF generally results in excellent aquatic and terrestrial habitat and supports a majority of recreational activities, while 200% of the MAF provides flushing flows.

Fixed percentage methodologies such as Tennant are more accurate when applied to mountain streams or protected rivers which exhibit essentially virgin flow (Prewitt and Carlson, 1979). Further accuracy is gained when flows are adjusted to account for upstream losses due to consumptive use, diversions or impoundments. It is recommended that stream sites be visited to observe and sample flow regimes equivalent to the flow which corresponds to 10, 30 and 60 percent of the MAF.

Northern Great Plains Method

This is a modification of the Tennant or Montana Method (Northern Great Plains Resource Program, 1974; Bayha, 1978). Flows for each month are ranked with the upper and lower 15% eliminated. The remaining flow data are used to develop a flow duration curve. This type of curve is used to determine the percent of time that specified discharges were equaled or exceeded during a given period of record. Monthly instream flow recommendations are based on 90% exceedence flows (i.e., flows are greater than stated values 90% of the time). However, it should be noted that this flow can be computed more easily by locating the 78% flow exceedence value. These recommendations can be adjusted to include the effects of inflow and diversion not measured by stream gages. Finally, adjustments can be made to account for target fish species and/or life history stage flow needs.

~ Discussion ~

The Narrative Justification Method represents a low cost method which, when used in conjunction with supportable hydrologic data, documents the relationship between the beneficial uses and the instream flow. Because the method is based on the judgmental expertise of the applicant, it is obviously a difficult method to defend if challenged. The primary use of this method is for applications on streams where there will be little or no controversy or challenge and where no increase in consumptive use is anticipated. However, because the method will save considerable time, effort, and money for the applicant, ADWR feels that this method is acceptable when used in the appropriate circumstances.

The Tennant Method has limited application, yet has been widely used for reconnaissance level surveys or other broad scale regional planning studies. It provides only minimal guidance for assessing streamflow and fisheries, wildlife and recreation requirements, but is easy and inexpensive to use. When applied, the stream's flow regime should be thoroughly understood. The method is best suited for large rivers with relatively low flow variability and extensive hydrologic research (Prewitt and Carlson, 1979). These conditions rarely apply to Arizona streams.

Due to the inherent weaknesses in the Tennant Method, numerous modifications have been proposed (see Appendix B). The Northern Great Plains modification results in recommendations which more accurately imitate mean monthly flows, while avoiding recommendations that would de-water a stream.

2. Habitat Retention Methods

Some of these simple incremental techniques may be applied to information gathered from either a single transect or multiple transects. Decision regarding the number of transects necessary to describe resource needs is dependent on whether resource needs for the claimed stream segment can be adequately described and met by flow requirements determined from a single location on the stream. Multiple transects may be necessary when more than one beneficial use is claimed.

In addition, the degree of controversy surrounding the instream flow application may aid in determination of the number of transects needed to determine beneficial use water requirements. Habitat retention method recommendations determined from multiple transects, while as yet to be challenged in the Arizona court system, may be able to withstand legal action. These methods may also serve to validate instream flow rate requests that are greater than median flow rates observed during periods of claimed beneficial use.

Single Transect Methods

Methods of this type are used to determine the flow which maintains the essential habitat requirements of a particular species or activity. A single transect is selected at a site considered critical to fish, wildlife or recreational uses. In the instance of fish species, this may be a critical riffle necessary for passage and spawning purposes. The assumption is that flows must be maintained at these critical sites for fisheries protection. Established criteria (depth, velocity and wetted perimeter) are used to determine the "limiting" factor for migration, spawning, incubation and other life stage requirements.

Hydraulic parameters may be calculated at various discharges using computer programs such as IFG4 or R-2 Cross. Average depth, velocity and percent wetted perimeter are assumed to change rapidly across critical riffles. Inflection points on wetted perimeter vs. discharge curves are used to identify flow recommendations. Recommendations are based on the lowest flow which meets minimum habitat retention criteria.

Minimum flows for recreational activities can be assessed using much the same methods. Hyra (1978) developed a "single cross section method" for determining minimum flows for various types of boating craft. His method assumes that a single cross section of the shallowest area along a stream reach can be identified and used to define flow requirements necessary to assure boat passage for the entire stream reach. Criteria are measured in terms of stream depth and width.

Width and depth parameters and associated flow can be calculated at different water surface elevations using the IFG1 computer program. When a calculated flow is determined to provide the minimum width and depth necessary for an activity, discharge is considered the minimum necessary to prevent significant loss.

Minimum stream depth and width for terrestrial wildlife species can also be assessed in the same manner. Maintenance of adequate stream depth is crucial for isolating and protecting sand bar and island nesting sites and streamside dens and burrows.

~ **Discussion** ~

While field effort is minimized thus reducing project costs, the lack of data seriously reduces reliability of projected streamflow needs. Subjective determination of critical site selection further weakens flow recommendations. This method is not recommended for use unless only one critical need or beneficial use exists.

Multiple Transect Methods

Typically, these methods include selection of at least three sites, each representative of a different habitat type (e.g. riffle, run, pool). Average depth, velocity, percent wetted perimeter are determined. Minimum criteria are established to determine "limiting" factors. Methods allow for comparisons among cross sections by averaging hydraulic property changes with flow or by selection of the most critical cross section.

This method may use R-2 Cross, AVE DEPTH, WSP or IFG4 hydraulic simulation programs to generate flow regimes and hydraulic parameters. The IFG4 model, one of the commonly used IFIM hydraulic models, allows the use of data collected from widely separated points in a stream, allowing for a more accurate representation of the available fish or recreational habitat or weighted useable area (WUA) of a stream segment. Flow recommendations from the WSP model are based on extrapolation of data obtained from a single flow rate. AVE DEPTH utilizes observed or predicted discharge-depth relations to empirically predict hydraulic properties. All four programs may be used to evaluate hydraulic changes in relation to species requirements at several flows through either direct measurement or extrapolation.

Composite graphs (from multiple transect) of velocity vs. discharge or wetted perimeter vs. discharge are used to show an inflection point. Below this point, reductions in discharge result in increasing losses of the hydraulic property. Inflection points are commonly used to establish critical flow levels. Users may evaluate hydraulic changes in relation to species requirements at several flows.

~ **Discussion** ~

Analytical capabilities are increased with this method. Effort is made to sample various habitat types or recreational use zones (e.g., riffle, run, pool). Hydraulic simulations provide habitat or recreational area-discharge predictions. In the case of fish species, although this method considers habitat, it does not relate habitat to fish standing crop (biomass).

These methodologies are limited to determining minimum flow requirements for a given activity or species. While some of these techniques may be able to withstand a legal challenge, they provide limited information. If a species is threatened or endangered or if a riparian area serves as a valuable recreation site, the determination of optimum flows, rather than minimum flows, through the application of an incremental technique may be more desirable.

3. Interdisciplinary Approach

Unlike most standard setting techniques, this method incorporates a variety of evaluation methods that not only assess resource needs and streamflow availability, but also address associated habitat and legal conditions. This process may also be used in conjunction with higher level single and multiple transect methods or incorporated into an incremental evaluation technique. The intensity of this evaluation is determined by beneficial use needs, the perceived level of legal challenge and current and future management objectives.

Interdisciplinary Method

This approach advocates an interdisciplinary evaluation process, rather than the use of specific methods, to assess streamflow hydrology, resource value requirements and legal aspects. The flexibility inherent in this process can create an assessment that is specific to the stream channel and resource values being evaluated. This may involve no more than a qualitative description of the relationship of the claimed beneficial uses and associated values with available streamflow or it may require a quantitative description. This approach may be amenable to legal challenge depending on the techniques selected to evaluate flow dependent resources.

The process for determining and protecting instream flow needs consists of six basic steps: (Jackson, Shelby, Martinez and Van Haveren, 1989)

1) preliminary assessment and study design
2) description of flow-dependent values/beneficial uses
3) description and quantification of hydrology and geomorphology
4) description of the effects of flows on resource values
5) identification of minimum flows to protect values and
6) development of a strategy to protect flows.

Initially, an interdisciplinary project team is selected to conduct preliminary field assessments and review literature to initiate plan development. Details assessed are identification of physical, biological and cultural values, project objectives, streamflow evaluation methods, time frame, budget needs and final products.

Stream values associated with beneficial uses identified in the preliminary assessment are then evaluated for their dependence on flows or flow-related conditions. Of particular importance are time patterns of flow regimes and channel morphology associated with high flows and channel dynamics.

Hydrologic quantification is usually expressed in terms of median daily flows by month. Where long-term streamflow data are not available, indirect methods may be used (see Instream Flow Hydrologic Assessment). Relationships may be developed between discharge and flow width, velocity, wetted perimeter and hydraulic radius using either single or multiple transect methods. Geomorphic techniques may be used to delineate processes as they relate to resource values and streamflow.

Determination of how alternative flow regimes affect flow-dependent resources may be accomplished by utilizing existing quantification methods when applicable or by simply describing flow-value dependencies. The level of sophistication used when determining necessary flow regimes may be dictated by not only cost and applicability of a technique, but by any controversial issues raised concerning the proposed instream flow. For instream flows likely to be challenged in court and for those applications requesting flow rates higher than the median, the data should be developed so that the relationship between required flows and resource needs are quantified or otherwise convincingly demonstrated.

~ Discussion ~

The Interdisciplinary Process can be utilized in a wide variety of instream flow situations. The level of effort needed to generate recommendations, based on this method, can vary considerably. Depending on circumstances, simple description and qualitative analysis of the beneficial uses dependent on flow maintenance may be adequate. Other circumstances may warrant the use of a standard setting multiple transect or incremental technique to quantitatively determine necessary flow rates.

B. INCREMENTAL METHODS

The previous methods discussed involve the selection of "critical reaches" followed by the identification of minimum flow needs based on the needs of claimed beneficial uses. These methods assume that if flows are sufficient in these reaches they will be sufficient along the rest of the claimed stream segment. Incremental methods, on the other hand, through the development of valuative judgements at a number of different flow levels, more completely document the relationships between flows and specified uses.

1. Fish Habitat Relationship System (FHRS)

The Forest Service FHRS is a series of computerized programs which include the General Aquatic Wildlife System (GAWS), COWFISH (a habitat capability model) and FISHSED (a stream sediment analysis program). These programs provide habitat capability information developed in the intermountain basin region for salmonids. Field data collected from Arizona waterways is necessary to modify FHRS to the State's specific stream characteristics and fish communities. FHRS is designed to provide information on spawning and rearing quality and quantity, over-wintering habitat and habitat condition index (improvement potential).

The instream flow portion of FHRS employs the Forest Service R-4 GAWS methodology, which is a habitat-discharge fish relationship evaluation. This method closely resembles the Instream Flow Incremental Methodology (IFIM) multiple transect procedures. Microhabitat parameters measured include velocity, depth and substrate which are used to derive probability-of-use criteria.

~ Discussion ~

FHRS has promise if it can be adapted to include warm water and threatened and endangered fish species, and if it can be modified to the physical characteristics found in Arizona streams.

2. Instream Flow Incremental Methodology (IFIM)

The Instream Flow Incremental Methodology (IFIM) was developed by the Aquatic Systems Branch of the National Ecology Center (formerly the Cooperative Instream Flow Service Group) and the U.S. Fish and Wildlife Service to provide a standard analytical technique for making instream flow recommendations. IFIM is an operational method of qualifying the effects of altered stream flow regimes on fish habitat. One of the initial objectives was to assess changes in fish standing crop (biomass) and species composition due to changes in streamflow (Bovee, 1978). It is the best method available to quantify changes in habitat that occur in relation to changes in flow.

An integral component of IFIM is PHABSIM (Physical Habitat Simulation), which includes the following components: 1) physical measurement of depth, velocity, substrate and cover; 2) computer simulation of stream hydraulics; 3) determination of species and life history habitat suitability curves and 4) calculation of weighted useable area (WUA) for each flow regime, fish species and life history stage. The hydraulic simulation predicts depths, velocities, substrates and the amount of preferred physical habitat (collective WUA) within a stream reach for a range of various discharges. From this simulation and knowledge of microhabitat preferences of resident fish, the amount of suitable habitat for a given species and life stage can be determined. Instream flows can be recommended based on the effect of incremental stream flow changes on the amount of suitable habitat. Because of its ability to predict habitat availability at different flow rates, this methodology allows for negotiation of flows between parties involved.

Either of two hydraulic simulation programs are used in IFIM; WSP program (U.S. Bureau of Reclamation, 1968) and the IFG4 program (Bovee and Milhous, 1978; Main, 1978). Although the WSP program has been used with some success (Cochnauer, 1976; Dooley, 1975; Elser, 1976; White, 1976), it has limited accuracy and is difficult to calibrate (Bovee and Milhous, 1978). WSP, however, is specifically designed to address difficulties inherent in the determination of flows of large rivers. WSP is capable of predicting flow regimes for unstable, shifting river channels, but is limited to low gradient streams (<5%). IFG4 is more accurate but requires field measurements from at least three sets of field data measured at different discharges (Orth and Maughan, 1982). However, this program was designed for relatively stable stream beds; when stream channels shift due to unconsolidated stream bed materials (e.g., sand and silt) then hydraulic predictions are invalidated. IFG4 is useful in determining flow regimes for both low and high (10%) gradient streams.

Recent developments of WSP and IFG4 provide for hydraulic data manipulations which have resulted in more accurate and efficient programs. It is now recommended that a single set of IFG4 measurements be used to calculate the velocity distribution across a channel. A stage-discharge relationship is then used to establish a rating curve using one of three methods: 1) log-log linear relationship between water surface elevation and velocity; 2) step-back order simulation using WSP or Hydraulic Engineering Center programs to establish stage-discharge relations or 3) a normal depth model using MANSQ or R-2 Cross programs. This mix of methodologies is referred to as the Combined or IFG4 Method.

IFIM relies on five basic assumptions:

1) depth, velocity, substrate and cover are the most important microhabitat variables affecting fish distribution and abundance,
2) the stream channel is not altered by changes in the flow regime,
3) depth, velocity, substrate and cover are all assumed to equally and independently influence habitat selection by fishes,
4) WUA indices can be generated from the critical microhabitat components; depth,velocity, substrate and cover preference factors and

5) a positive linear relationship exists between WUA and fish biomass (i.e., fish populations are implicitly assumed to be habitat limited).

~ Discussion ~

The most difficult problem in recommending flows for fish species is relating the physical characteristics of the stream to the ecological requirements of the fish. A further aggravation to the situation is a lack of information on the ecological requirements of certain fish, particularly specific microhabitat requirements. Owing to the multitude of physical, biological and environmental interrelationships in aquatic ecosystems, it is difficult to accurately predict effects of flow alteration on fish standing crops and habitat carrying capacity.

Although inherent problems exist with this methodology, it provides the best information available on the effect of a given flow regime on fish habitat. In addition, it makes these predictions for each life history stage for several species of fish.

The IFIM is the only methodology available which allows for negotiation of flows. For this reason this technique may prove valuable for those streamflow situations where maintaining optimum flows, rather than minimum flows, is desired. The IFIM methodology is still evolving as new developments, refinements and manipulations occur. These changes serve to reduce past weaknesses and criticisms of this methodology.

3. Incremental Approaches for Recreational Use

Incremental approaches for evaluating recreational use employ some level of qualitative assessment to determine flow levels that provide the best opportunity for use. Streamflow requirements vary for each recreational activity, the level of expertise of the targeted user population(s) and stream channel characteristics. To determine these flow requirements both expert and general user values and recommendations may be utilized.

Probability-of-Use Approach

Hyra (1978) developed an incremental method using a computer simulation model that utilizes similar techniques to those employed by fishery assessment models. Assumptions to the modeling approach include:

- ✓ recreation quality can be adequately explained by depth and velocity,
- ✓ a linear relationship exists between surface area and recreation quality,

- ✓ minimum, maximum and optimum depth/velocity combinations can be determined for recreation activities,
- ✓ weighted surface area that meets specific depth/velocity requirements best determines recreational use potential.

The method is comprised of four steps: 1) depth and velocity simulation of a stream reach; 2) determination of depth and velocity combinations and the resulting stream surface area; 3) determination of the composite probability-of-use (PU) for each combination of depth and velocity, and 4) calculation of the weighted useable surface area.

The PU of depth and velocity for a specified recreation activity are represented on a scale of 0 to 1, where 0 indicates minimum or maximum depth or velocity for a use, while 1 indicates optimum recreation use depth or velocity. Physical limitations determine minimum and maximum levels. Optimum levels indicate the preferred range.

Hyra (1978) developed PU curves for different activities, designating 0.5 as the PU at which half of the recreationists will consider the depth or velocity safe for use. A graphical presentation of PU is provided by PHABSIM.

Probability of use curves must be calculated for each specific stream reach and should not be generalized to different reaches where primary recreational uses are different. In addition, Hyra states that no single valid optimal flow exists for recreational use in general.

Recreational User Survey Approach

A large number of studies have been based on user surveys to obtain judgements about the relationship of flows to recreation-related variables. Participants in these studies may experience a single flow rate, a range of flow rates or be exposed to photographic and/or verbal descriptions. In a study conducted by Moore et. al. (1990) actual flows experienced by interviewed participants in Aravaipa Canyon Wilderness were recorded. User responses were then statistically related to measured flows.

Visitors were asked whether they preferred the flow rate they encountered, or would have preferred higher or reduced flows. Responses were compared with gaged flow observed at the time of the visit, revealing that participants generally preferred average flow rates over higher or lower flows. At low flows pools become less useful for swimming and wading. At high flows riffles, pools and associated geologic features are obscured.

~ **Discussion** ~

These studies develop valuative judgements of the quality of specific recreational activities at different flow rates. The result is a more complete documentation of the relationships between flow rates and recreation. Researcher-generated "probability of use" curves are used in Hyra's (1978) incremental method to depict hypothetical relationships, while in the Aravaipa Canyon study curves based on users' evaluations of a range of flows were developed. A common critique of these methods is that inadequate "knowledgeable" user sample size can result in unrealistic "probability of use" curves.

These types of studies generally produce a similar shape curve that describes the relationship between flows and recreation quality. Flows somewhere in the middle flow range are considered optimum, while both high and low flows are less acceptable to unacceptable. The specific points at which flows are considered at these levels varies with channel size, recreation activity and level of skill of the recreationists. Hyra recommends local calibration utilizing local expert assessments to validate PHABSIM recreation suitability curves for the stream reach and associated recreational uses.

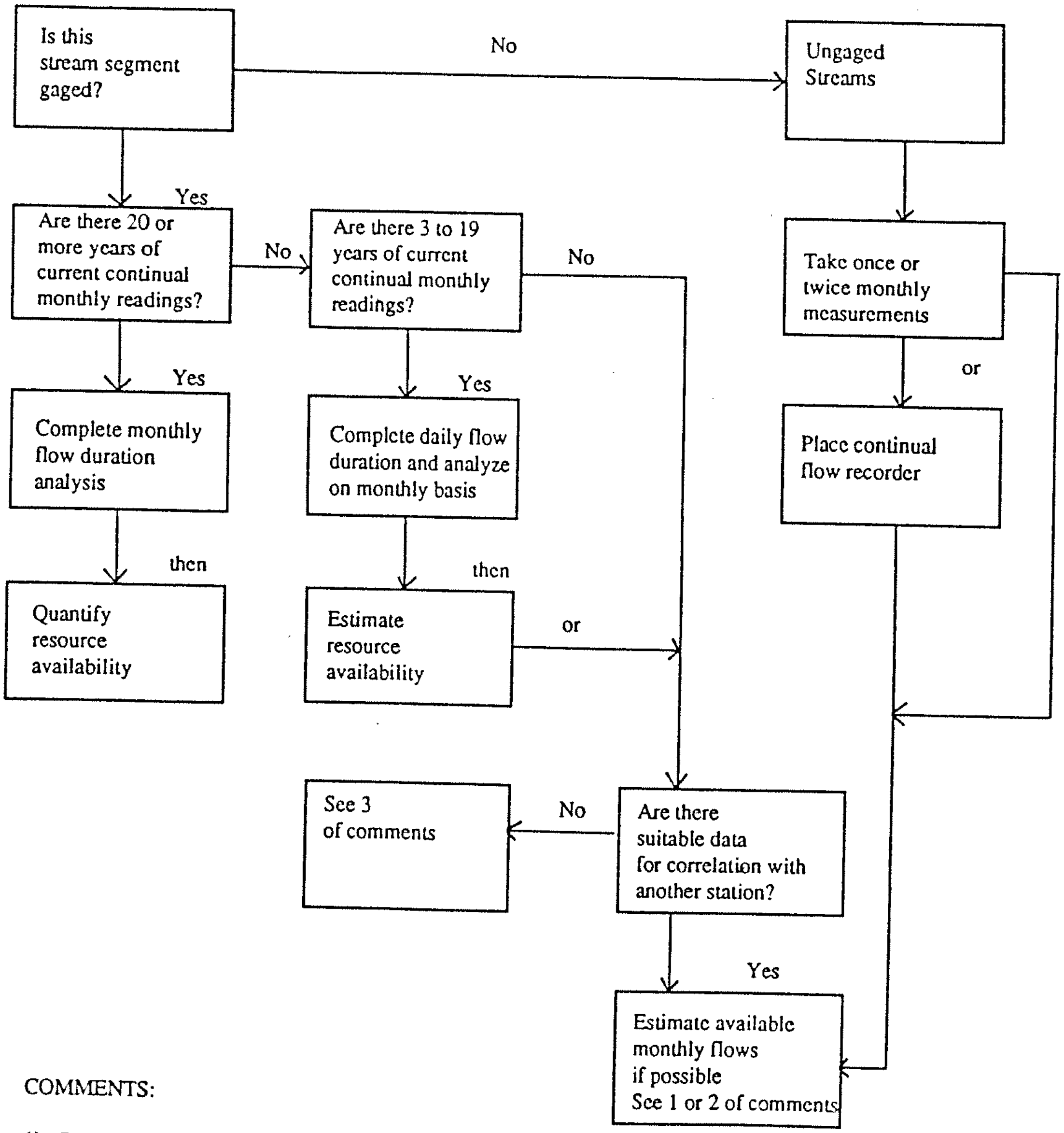
IV. INSTREAM FLOW HYDROLOGIC ASSESSMENT

In order to support an instream flow request an applicant is required to develop a hydrologic assessment of streamflow specific to the applied for stream reach. The hydrologic assessment has two primary functions, 1) to demonstrate that the requested flows will occur when the requested beneficial use is being made and 2) establish an interrelationship between applied for beneficial uses and available streamflow. Because an instream flow applicant does not have to construct diversion structures to put streamflow to beneficial use, instream flow rates requested in the application, which are consistent with available streamflow, are the measure of the beneficial use. Instream flow applications cannot request an improbable quantity of streamflow to support the requested beneficial use, therefore, the applicant must establish the quantity of water required to accomplish the purpose of the appropriation. Median rather than mean flow rates should be used in most hydrologic assessments due to the skewed distribution of daily flows resulting from infrequent high flows. Generally, the median flow rate, or middle value when flow data are ranked in order of magnitude, provides the most probable determination of flow available in a stream.

The goal of the hydrologic assessment is to characterize a flow regime which approximates streamflow conditions associated with the location and duration of beneficial use. A hydrologic assessment is usually easy to complete where gaging station data are available for the stream. However, many streams in Arizona are ungaged. Assessment of these streams in a manner consistent with streams for which gaging records are available may not be possible. In such streams, virtually any data are valuable even if they are developed from once or twice monthly random measurements of streamflow. For both gaged and ungaged streams, any data gathered can provide valuable insight to the flow regime of the stream and aid in assessment of water available to support an instream flow.

Before beginning hydrologic assessment of a particular stream to develop an instream flow request, preliminary evaluation of data available for the stream is necessary. Examination of the diagram shown in Figure 2 provides insight into the assessment process.

Figure 2. Summary flow chart for instream flow hydrologic assessments.



COMMENTS:

1) - Determine if 20 or more years of suitable flow data are available.

2) - If 20 years of suitable data are not available, evaluate as a stream with 3 to 19 years of suitable flow data or assess as a stream with available once or twice monthly measurements.

3) - Complete as a stream with available once or twice monthly measurements.

Some of the various methodologies which can be used to construct a hydrologic assessment for both gaged and ungaged streams are described briefly below. These assessments range from determination of median flow rates derived from random, instantaneous measurements, to analysis of streamflow data obtained from gaged streams using flow duration and correlative techniques. Rantz (1982) and Buchanan and Somers (1980) describe several techniques for measurement and determination of streamflow.

In order to achieve specific resource objectives, such as requesting flows to meet optimum rather than minimum beneficial use needs, or if it is determined that a more intensive analysis of the data may provide evidence that a greater amount of flow is available for claimed instream flow use(s), the applicant is encouraged to develop an assessment which exceeds the minimum technical requirements.

A. GAGED STREAMS

Assessment of stream flow available to an instream use is usually easy when an active gaging station with a significant period of record is located nearby. A stream gage is considered suitably located if it is capable of providing a direct assessment of water quantity without resorting to indirect methods. Stream gage records for existing or discontinued gaging stations can be obtained from the U.S. Geological Survey. Flow data may also be available from the U.S. Bureau of Land Management, U.S. Forest Service, U.S. Bureau of Reclamation, or university libraries. If adequate flow data are available, the flow characteristics of a stream may be analyzed using various statistical techniques such as flow duration analysis.

1. Flow Duration Analysis

A flow duration curve can be used to assess the flow characteristics of a stream. The curve shows the percent of time that specified discharges were equaled or exceeded during the period of record.

To develop an assessment using a flow duration curve, monthly or daily flow volumes are arranged in a rank order tabulation and, for select values of flow exceedence, plotted month-by-month as mid-month values. Records of at least twenty years in length are usually required when an assessment is based on monthly flow volumes. If part of the most recent record is missing, and additional preceding years of data are available, then an extension of the record may be necessary to recover the last twenty years of supporting data for the analysis.

Some gaged streams, however, do not have twenty years of record. Where three to nineteen years of record are available, a flow duration analysis based on monthly flow volumes is not feasible. Confidence limits for such an analysis deteriorate with a smaller sample size. However, other correlative methods are available which may prove useful when preparing an assessment with records of short duration. Flow duration evaluations, based on mean daily flows, can provide a reasonable assessment where as little as three years of record are available. Where records provide less than three years of data, the average monthly flows for each calendar month are generally sufficient for an initial estimate. However, averages derived from short term records can be biased by high or low flows.

Assessment of gaging station data should include an examination of the record for atypical effects. Operation of dams, diversion of streamflow or discharge of effluent can reduce or increase streamflow which, although not natural in their affect, may become important factors in developing an instream flow request.

~ Discussion ~

The most recent twenty years of record is adequate to develop a water supply based on a flow duration analysis of monthly flow volumes. Periods of record less than twenty years in length may require a more intensive analysis such as examination of mean daily flows to complete a flow duration analysis, or alternative correlative methods.

2. Extending Short-Term Records

Some streams may have gaging station records of only a few years in length. Where a gaging station has substantially less than twenty years of continuous, current record, it may be more desirable to reconstruct a correlated record of monthly flows for the missing portion of the most recent record than to complete a more intensive analysis based on a shorter period of record. Use of a longer, continuous period of record provides a greater data variation thus enabling a flow duration analysis to be completed for monthly flows. Since instream flow analyses may have beneficial use considerations which examine consistency in monthly flows distributed on a seasonal or annual basis, an extended period of record would also improve this assessment process by readily providing a month-by-month flow history.

Extension of streamflow records using linear regression techniques is well documented in the literature. Linear regression of two concurrent records (one of them being a record of interest) is used to estimate missing values in the record of interest by comparison with the base period of record of a similar nearby gage. A principal consideration in completing any such reconstruction is that variations in the base period of record of the station providing the basis of the reconstruction, or x values, be present or assumed present in the record of interest being reconstructed, or y values. When these concurrent values are plotted as a scatter diagram of related flows for individual months, they usually plot in a nearly straight line. Baseflow conditions or other natural variations present in one record but not in the other may cause the relationship portrayed by the points to become non-linear. Usually such non-linearity is seen to have a predictable nature which is not adverse to the record reconstruction. In both cases, however, the line-fitting procedure may be simply done by eye. Reconstruction of the record of interest is completed by comparing the data for the base period of record where monthly values are present to months where values are missing for the record of interest. Missing values can then be estimated from the best fit line.

To reconstruct an extended period of record for a stream gage, the following criteria should be maintained:

1. Streamflow should be relatively free from intervening effects of extensive regulation, storage, or diversion.

2. A suitable primary station should be available for correlation.

3. The maximum standard error of estimate or spread of about two-thirds of the annual runoff values about the correlation line should be less than about 30%.

4. The coefficient of correlation should be at least 0.80 for data evaluated as fit-by-eye.

~ Discussion ~

This and other similar correlative procedures possess value in extending some streamflow records. However, the amount of data necessary to obtain a satisfactory level of correlation between stream gages may limit the applicability and use of some techniques.

B. UNGAGED STREAMS

The vast majority of streams in Arizona have no gaging station records. Applicants must be prepared to measure streamflow where gaging station records are unusable or non-existent. To determine streamflow availability in these streams it is necessary to initiate a program of periodic, on-site instantaneous measurement of flows or to establish a continual flow measurement device. Selection of an appropriate site and utilization of an applicable technique is important for acquiring streamflow information in an accurate and cost effective manner. Streamflow measurement sites should be located in areas that provide both channel width and depth stability. Subsequent measurements should be taken at the same site(s).

Quality of data is particularly important when collecting instantaneous flow information. When an instream flow assessment will be based on the minimum data standards, close attention should be given to activities or events that result in abnormally low or high flows. An applicant should limit data collection to streamflows that are "representative" or "typical" for the flow period of interest (month or season). This includes accounting for upstream diversion activities.

1. Instantaneous Flow Measurement

Instantaneous flow measurement techniques involve dividing stream width into portions or sub-divided segments of the cross-sectional area and measuring the velocity of flow through each segment using a current meter. For individual segments, the discharge is the product of the flow velocity and the area. Summing the corresponding velocity and area calculations of all segments yields an instantaneous value of the streamflow for the total cross-sectional area.

Streamflow velocity may be measured by stretching a surveyor's tape or tag line across a stream at right angles to the axis of streamflow. Survey tape methods can provide a disadvantage in that even though tension is applied to the surveyor's tape, its weight will cause it to sag. To determine actual streamflow with this method, field data must be corrected to a level (horizontal) reference line. Fortunately, most stream channels in Arizona are not very broad and the tape is essentially stretched tight enough to produce a level reference line.

2. In-Place Flow Measurement Devices

Another way to accomplish streamflow measurement is to establish an in-place streamflow measurement device such as a stage gage. A non-recording stream-gaging station, such as a staff gage, or a recording stream gaging station can be used. A recording stage gaging station produces a continuous time-stage graph. Stage is converted to discharge using a stage-discharge relationship developed specifically for the gaging station. These stations should be located in a cross sectional area of the stream channel (as measured in a vertical plane perpendicular to the direction of streamflow) that is composed of more or less non-erodible streambed and banks. Sufficient data will need to be collected to establish a stage-discharge relationship at the location of the gage or recorder. Periodic review of the channel cross section and discharge will be necessary to determine if any shift in the channel has significantly altered the stage-discharge relationship. Many Arizona streams experience frequent, significant cross sectional changes. Where significant changes have occurred, appropriate adjustments must be made in subsequent discharge estimates.

~ Discussion ~

Installation of streamflow measurement devices not only provides greater continuity of collected data, it also allows for a more thorough assessment of available water resources. Gaging stations, particularly those equipped with continual recording devices, can be expensive. On-site stream gage installation, while preferred, will usually not be required. However, when a program of periodic instantaneous flow measurements is undertaken, the applicant must be prepared to carry it out on schedule in order to avoid critical data gaps. Some gaps in data can be avoided by installing staff or crest gages when frequent high flows make streams inaccessible to wading and measuring currents.

C. HYDRAULIC SIMULATION

This streamflow evaluation technique can be applied to data collection from gaged or ungaged streams to assess instream flow use needs and/or streamflow availability.

After several site specific flow measurements have been collected, a specified minimum flow is determined based on a simulation of the measured range of flows. This is done to determine flows required to maintain a certain desired instream flow use or to develop a stage-discharge relationship to estimate streamflow at a particular fixed location. Because hydraulic variables used in the determination of flow change with variations in depth and velocity, an appropriately calibrated simulation is required. To accomplish this, site-specific flow measurements must be collected from the full range of flows likely to occur. Calibration of the simulation is realized when hydraulic variables, taken as a function of depth, yield flows equal to the measured flows determined during field surveys.

When high flows occur and stream channel morphology is altered, it may be necessary to use flow modeling techniques to analyze flow conditions and to verify velocity and depth at the desired level of flow. General calibration standards applicable to hydraulic simulation dictate that the amount of error between measured and simulated flows be less than the error in the measured flow, regardless of the simulation technique used.

~ **Discussion** ~

This methodology has value in that it can be used to assess streamflow availability for a particular instream use or to develop a stage-discharge relationship. This type of technique has also been used to synthesize flow data for ungaged streams using gage data obtained from stream gages located upstream or downstream of the proposed stream segment or located in a stream in an adjacent watershed. However, while this technique can be used to synthesize data it does not substitute for on-site streamflow measurements.

V. SUMMARY

To support an instream flow application an applicant must 1) quantify the amount of streamflow available during the periods of claimed beneficial use and 2) quantify the relationship between claimed flows and beneficial uses. The streamflow data and report submitted to the Department must, at a minimum, be commensurate with the minimum criteria described in Section II of this report. Additional data and information may be required depending on the complexity of the stream system and associated uses and/or legal issues.

Methods to evaluate instream flow and beneficial use flow requirements are divided into two basic categories, standard setting and incremental. These methods, when used in conjunction with adequate hydrologic data, can be used to support an instream flow claim. Standard setting methods are categorized as either "non-field" or "habitat retention." These methods are generally applicable to streams that are currently not diverted or provide limited consumptive use opportunities. Methods such as Tenant or Northern Great Plains can provide general information regarding fish, wildlife or recreation use needs. The Narrative Justification Method provides a qualitative description between streamflow and claimed beneficial uses. Habitat retention methods, such as single and multiple transect, are used to determine the "limiting" factors associated with the claimed stream segment. These methods can be species and/or activity specific, but are limited to determining minimum streamflow requirements. Single transect methods are recommended when only one beneficial use is claimed and the necessary streamflow for that use can be adequately determined utilizing one transect. Habitat retention methods, unlike non-field methods, may provide information that is supportable if legally challenged.

The Interdisciplinary Approach combines elements of other techniques. Element selection is dependent on resource needs and legal issues associated with a particular stream or stream segment. Standard setting or incremental methods may be used to determine streamflow requirements. This approach is based on the evaluation of multiple resource needs and stream channel attributes in respect to the maintenance of a particular streamflow rate. Incorporation of multiple transect or incremental techniques may make this approach defensible.

Because incremental methods more completely assess the relationship between streamflow and specified beneficial uses, these techniques are the most defensible. However, they are the most expensive and labor intensive. The IFIM can be used is to assess streamflow for several fish species and some recreation activities. Techniques, such as the FHRS, show promise if they can be modified to accommodate Arizona stream characteristics and flow requirements for non-salmonid species. Incremental techniques can be applicable to situations where documentation of the effect of multiple flow rates on species habitat or activity quality are necessary. These situations include, but are not limited to, heavily diverted streams, streams with regulated flows or flows that are largely supported by effluent discharge.

Fewer incremental techniques have been developed for recreation uses. Valuative judgements developed from techniques, such as the Probability-of-Use or the Recreational Survey Approach, should be based on multiple flow rate observations by local experts.

Quantification of streamflow depends on streamflow data availability. When twenty or more years of current, continual data is available streamflow may be quantified utilizing a monthly flow duration analysis. When less than twenty years of current, continual data is available a daily flow duration analysis may be completed on a monthly basis. Another strategy may be to correlate data with that collected from another station.

Current, continual flow information does not exist for most Arizona streams. If flow data for a particular stream or stream segment are not available, it is necessary to install a continual flow recorder or to initiate collection of once or twice monthly flow measurements.

A minimum of one year of streamflow data collected on-site on a monthly or seasonal basis is necessary to obtain a permit to appropriate (See Section II). Drought, flood events and diversion activities can substantially affect streamflow. When limited data, particularly instantaneous, are all that is available to quantify streamflow, it is critical that data collection occur when streamflow is "typical" for the month or season in question. To maintain randomness in the data collection more than one monthly measurement or three seasonal measurements should be obtained.

To determine which data collection procedures and data evaluation techniques are most applicable to a particular stream or stream segment, an instream flow applicant should meet with Arizona Department of Water Resources personnel prior to initiating the streamflow evaluation process.

VI. GLOSSARY

Baseflow - The part of a stream discharge resulting from groundwater seepage.

Beneficial use - Beneficial uses recognized by the State of Arizona that can be accomplished without diversion include fish, wildlife and recreation uses.

Critical reach(es) - Areas of a stream where a species or an activity are particularly sensitive to changes in flow levels. These areas contain micro-habitat that is essential to the survival of a species. They are generally spawning areas or riffles that restrict passage.

Discharge curve - Depicts the volume of water observed flowing in a stream past a specific point in a given period of time.

Habitat carrying capacity - The number of animals a habitat can maintain in a vigorous, healthy condition.

Habitat suitability curve (criteria) - A component of an IFIM model. Is the relative value of a specified range of micro-habitat variables (depth, velocity, substrate and cover) for the successful completion of life stage requirements of a selected evaluation species.

Hydraulic properties - Are represented by mean velocity, mean depth and width of flowing water.

Inflection point - The "break" point in the relationship between two variables. Is generally used to determine minimum flow requirements.

Mean streamflow rate - Is the sum of all streamflow measurements in a sample divided by the number of measurements in the sample.

Median streamflow rate - Is the midpoint between the two streamflow measurements in a set of data.

Minimum streamflow rate - A flow rate that provides enough water to meet the basic needs of a particular species or activity at or near subsistence level. Provides enough water for species survival, but not necessarily enough for good health, optimum growth, vigor or fecundity.

Optimum streamflow rate - Adequate flow is available to meet all the needs of a species or activity. Productivity or use should be high as a result. Health, growth and fecundity will approach the maximum for a given species.

Pool - Common bed form produced by scour in meandering and straight channels with relatively low channel slope.

Riffle - Shallower reaches of a stream where it flows across gravel bars.

Riparian area - An aquatic or terrestrial ecosystem that is associated with bodies of water such as streams, lakes, or wetlands or is dependent upon the existence of perennial, intermittent or ephemeral surface or subsurface water drainage.

Rule-making process - An administrative process that establishes standards for the implementation of statutory law.

Run - Small, swift flowing stream or stream segment.

Weighted useable area - Is an index that represents the amount of suitable habitat for a given species and life stage.

Wetted perimeter - The total length of a cross-section at the interface between a channel bed and the stream which occupies it.

VII. APPENDIX A

Sample form for Application for Permit to Appropriate Public Water of the State of Arizona

Arizona Department of Water Resources
15 South 15th Avenue
Phoenix, Arizona 85007

(
(No. ____________________
(
(Filed: ____________________
((for office use only)

APPLICATION FOR PERMIT TO APPROPRIATE PUBLIC WATER OF THE STATE OF ARIZONA FOR INSTREAM FLOW MAINTENANCE

1. Applicant: ____, telephone ______________

   Address: ____

2. Type of water source and name: ____

   being a tributary to: ____________________ on the ______________________________ watershed
   (for office use only)

3. Describe the proposed use of the instream flow appropriation for either wildlife, including fish, and/or recreation:

   ____
   ____
   ____
   ____
   ____

4. Amount of Instream Flow appropriation requirement, described as a rate per month:

Proposed Use	Instream flow requirement (cubic feet per second/month)
Wildlife	________________________________
Fish	________________________________
Recreation	________________________________

5. Location of proposed instream flow appropriation: Describe entire reach or segment of location of proposed appropriation, by legal land parameters. Also attach a United States Geological Survey topographic quadrangel map clearly showing the location of the entire reach or segment of the proposed instream flow appropriation:

GLO Lot #	or	1/4	1/4, of Section	Township N/S	Range E/W
______	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______
______	______	______	______	______	______

6. Owner of land on which the proposed instream flow appropriation is located: ____________________

   ____

   Does the applicant have legal access to the proposed stream segment?

   Yes ________ No ________ If "No", explain in item 8 below.

7. Is the water to be used supplementally with other water(s)? Yes__________ No__________

If "yes", identify other waters or water rights, and explain: ______________________________

8. Additional Comments or explanations: ______________________________

9. Attach examination fee of $25.00.

To support an instream flow claim an applicant must develop a study that; 1) substantiates that streamflow requested in item 4 is available at the rates specified and 2) quantifies the relationship between a claimed beneficial use(s) and requested streamflow rates.

The study should be submitted at the time of filing the appropriation application, but must be submitted no later than two years after the filing date.

Submit the completed application, with examination fee, to the *Arizona Department of Water Resources, Operations Division, 15 South 15th Avenue, Phoenix, Arizona 85007.*

Date

Signature of Applicant, or Representative

DWR 33-1H

VIII. APPENDIX B

List of additional instream flow methodologies not mentioned in text

Methodology	Citations	Brief Description
Habitat Mapping		Uses multiple transect to derive areas of suitable depth, velocity, substrate. Minimum flow provides 75% of maximum possible spawning habitat.
Hoppe	Hoppe (1975)	Reconnaissance level method. Flow recommendations for salmonid spawning and early life history stages.
Hunter Creek	Boaze & Fifer(1977)	Modified R-2 Cross. Samples several critical sites and habitat types over a range of 7 flows. No computer simulation. Relates habitat criteria to fish requirements.
Idaho	White(1976) Cochnauer (1976)	Large rivers. Transect at critical spawning, rearing, passage sites. WSP used; habitat-discharge plotted.
Oregon	Pruitt & Nadeau (1978) Thompson (1974)	Uses weighed D, V criteria. Based on electivity curves. Similar to IFIM use of curves and WUA. Considers life history stages.
Useable Width		Single cross section measured at multiple discharge. Similar to wetted perimeter. Develop W, D criteria. Recommends flow where 25% total width and 10% length useable.

Methodology	Citations	Brief Description
USFS Region 4	Dunhan & Collotzi (1975) Bartschi (1976)	Transect run at selected sample stations at 1 low (index) flow. Habitat ranked by pool size, substrate, streamside cover. Computer generated habitat-discharge plots. Recommend flow at 80% of index flow habitat.
USFS Region 6	Swank & Phillips (1976)	Hydraulic features measured at representative sections. Several flows evaluated. Spawning, rearing, food production criteria used. Optimum flows are recommended.
Washington	Collings (1974)	Select 6 spawning & rearing sites. Five discharges measured. Flows plotted v. spawning and rearing habitat. 75% of optimum spawning flow recommended.
Waters or California	Waters (1976)	At least 600 D, V measurements collected. Three flows studied. Plots habitat quality v. flow.
Wesche (Modification of Tennant)	Wesche (1974)	Minimum flows = 25% of MAF for trout summer rearing flows.
Wetted Perimeter	Orth & Maughn (1982) Collings (1974) Cochnauer (1976)	Reconnaissance-level method. Assumes relation between wetted stream channel and rearing habitat. Transect located at riffles.

WRRI Cover	Wesche (1974)	Small brown trout streams. Transect at each representative reach, 4 flows. Cover measured, rating equation applied to flows. Recommend low flow that maintains cover. Good correlation of cover v. fish standing crop.

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